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# Aristotle, Space and Time

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There are two fundamentally different conceptions of the nature of space and time. On the one side, and particularly associated with the ideas of Newton, is what is now called "substantivalism", which sees space and time as existing objects, over and above the other material objects and processes of the world. On the other, and particularly associated with the ideas of Leibniz, is the "relationalist" approach, denying the existence of space and time as objects in their own right; seeing them rather as relations between material objects. This paper explores and defends Aristotle's relationist account of space and time, in the light of subsequent developments of physics.

## Relationism

In the Physics, Aristotle develops what is today called a relationist account, denying that space and time have any independent existence, over and above the existence of material things and processes and the relations between them.

The major problem for such an approach is that of the forces generated by non-inertial motion — like centrifugal forces. Some forms of accelerated motion produce such forces, some do not. The forms of accelerated motion that do not produce such forces always turn out to be movements only relative to accelerated motions that do produce such forces — as in the case of the "movement" of the stationary train, relative to the train slowing down or starting up beside it.

Newton argued that the latter sorts of accelerated motion must be motion relative to a fixed structure of absolute space. This space is not only a container within which matter is located but also enters into causal relations with material objects. Whereas constant velocity in a straight line — inertial motion — produces no resistance from absolute space — so that absolute velocity has no physical consequence — acceleration does produce such resistance.

As Newton argued in relation to his bucket experiment, once the water in a spinning bucket has caught up with motion of the bucket, its concave surface cannot be explained in terms of motion relative to the bucket, and has to be understood as a consequence of motion relative to absolute space.

For a relationist, the measure of the duration of a process A is just a comparison with the duration of another process B. Clocks are essentially processes of regular and repeated oscillations that can be counted to provide a measure of such duration. But a particular measure of such relative time can be found which renders accelerated motion non-accelerated, and if some acceleration is absolute, so must the measure of such acceleration be absolute; this is time in itself. A clock which gives any other result is wrong.

## Causation

In sharp contrast to the Humean view which sees causes as discrete events, contiguous with their effects, Aristotle sees causation as an extended process of interaction between a moving cause — a thing capable of acting — and a thing moved — a thing capable of being affected by such action. Such a moving cause is a substance, a compound of matter and form able to exercise its causal power by virtue of its form, acting upon another such substance to change the form of that thing's underlying matter. Change of essential properties of form turns the thing acted upon into a different kind of substance.

The change is a continuous process of transformation of the object of the causal power up until the point at which a particular result has been produced. For Aristotle this means that every part of the change is itself a process of change, no matter how small an interval of time is considered. As he says, "being continuous is being divisible by infinity" (*Physics*, 200b:12–28).

## Infinity

He cites a number of reasons for investigating the infinite, including the seeming infinity of time, both in extent and in divisibility, the seeming infinite divisibility of magnitudes and our power to imagine the infinite as +1 added to any number – "infinity by addition".

He argues that space, while not actually infinite in extent, is infinitely divisible, or more specifically, it is infinitely divisible in potentiality, although a process of division could not be actualised in reality. No actual process of division — in theory or in practice — could ever reach completion, it can go on without end.

This idea is quite compatible with contemporary mathematics where $f(x) = 1/x$ approaches infinity as x approaches 0, but never actually gets there, since 1/0 is undefined. As Oderberg says, "potentiality, in the form of the limit, is built into the fabric of mathematical thinking"(Oderberg, 2006:108).

## Space

Aristotle says that change is impossible without place, void and time. But he goes on to dismiss the possibility of a void, and thereby to refute the atomists conception of a universe of infinitely many solid and uncompressible particles moving in an otherwise empty but infinite space. As Parmenides said, void as what is not anything cannot — logically — be.[1]

More generally, Aristotle dismisses the idea of space as container of matter, whether such a space is itself conceived as substance or as void. When we displace the contents of a physical container it seems as if there is an empty space as extension capable of independent existence. But, what has really happened is that one kind of matter — water for example — has been replaced by another — typically air. The universe is, in fact, a fluid continuum of constantly interacting and transmuting (divisible and compressible) physical elements — with no "empty" spaces between them. And if material things "needed" some sort of substantial container space to occupy, then space as substance would require its own space — and so on.

As Aristotle says, the place of a thing is not a location in a pre-existing, potentially or partially empty — container, but rather the limit of materials surrounding the thing in question. We identify its place by reference to the nearest unmoved material surrounding it; its distance and direction relative to other things in the room, in the city, on the continent etc.

It's true that Aristotle's cosmology, of concentric spheres of materials centred upon the earth, could be seen to imply some idea of absolute space, with earth at the centre of such a space. But his discussion of place makes perfect sense understood in terms of an inertial reference frame — with objects located by reference to a system of other such objects retaining their mutual spatial relations of distance and direction by virtue of being subject to no (net) force. The place of a thing is its spatial relation to other elements of such a reference frame, rather than to any sort of absolute space.[2]

## Time

Time is continuous because time involves change and change is continuous. The time it takes for A to travel to B corresponds directly to a change of place. While time is not itself change it is "that in respect of which change is numerable" or the measure of motion, "the number of change in respect of before and after" (*Physics*, 220a, a24–25).

Just as space is not an absolute framework, parts of which may or may not be occupied by particles of matter, neither is time an absolute framework within which change may or may not take place, rather it is a quantity of change. Neither of them are substances, with their own essential matter and form, and their own causal powers grounded in such matter and form.

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1 Democritus also fails to consider the cause of motion of such particles or to consider that bodies whose rate of fall is proportional to the density of the medium through which they fall would achieve infinite velocity in a zero density medium — which is not possible.

2 An inertial reference frame is one in which some basic structural elements move together in a straight line at constant speed relative to another such frame by virtue of not being acted upon by any (net) force. Such a frame, as a whole, is not subject to acceleration effects [so-called inertial forces, including centrifugal force] , though the operation of local forces to produce accelerations can be observed within such a frame. Such reference frames move uniformly, at constant velocity, relative to each other, with identical – internal – experiments in different frames yielding identical results.

As noted, for a relationist, the time of one process of change is measured by reference to another such process, preferably a regular oscillation that allows for a count of such oscillations. Aristotle refers to the regular oscillation of "the heavenly sphere" as the change against which "all other changes are measured" (*Physics*, 223b, b21–24).

Aristotle describes the "now" as that which holds past and future as a continuous whole. The "now" as duration-less limit,"the end of the past and beginning of the future," that unites past and future as continuous, is a potential rather than actual reality. He is clear that the duration-less now "is not part of time. ... time ... does not seem to consist of nows" (*Ph*, IV, 218a, a3–7). Because time is the number of something continuous, "it is continuous itself" (*Ph*, IV, 220a, a26). As phenomenologists, psychologists and some metaphysicians have emphasised, the "now" as a lived reality always has some duration within which the past fades and the future manifests; a duration or continuum of presentness.

## The Continuum

On one influential contemporary view, space and time — as continua — are composed of an infinite number of dimensionless points. Between any two points is always a further point, so that no two points are right next to each other. Defenders say that because all the gaps are filled, this is indeed a continuum. Critics say that the failure of points to be in contact with one another means that this cannot be a genuine continuum, in the sense of being gap free and seamless. Aristotle says that two things are continuous only if their limits are identical — such that the end of one is the beginning of the other (see e.g. Dainton, 2010: ch 16).

Real material objects cannot be thought of as composed of zero sized points. Real material things are quite different from abstract things like sets of numbers. Just because mathematicians have found ways to assign magnitudes to infinite collections of abstract entities this has little relevance to understanding real material things.

It has been said, by Graham Priest (Priest, 1987:218) and others, that the contemporary view falls down on a substantival view of space — or spacetime — as concrete material thing, since a substantial space could not be composed entirely of zero-sized parts. Aristotle is rejecting a substantival account of either space or time — as substances separate from the actual processes of change (or persistence) of matter and form — with their own causal powers or capacities. But he does have an idea of the cosmos as a — substantival — continuum of matter-in-process. And this continuum is quite different from the contemporary mathematical model of a continuum. Any part of Aristotle's continuum, however small, is composed of further and smaller extended parts, and so on, without end. This is quite different from the idea of parts that do not themselves possess parts, and are not themselves extended, as dimensionless points.[3]

[3] As Oderberg points out, it is still possible to assign some sort of reality to "instants" in an Aristotelian account, as limits of division of a time interval. Just as there are no actual infinities, so are there no actual

## Zeno

Zeno's arguments are central to Aristotle's discussion of space and time in the Physics. Critical engagement with Zeno's Parmenidean refutation of plurality, motion and change plays a central role in the development of Aristotle's own ideas of time and space.

One way to understand Zeno's four paradoxes is to see the first two, the dichotomy and the Achilles, as showing the impossibility of motion on the basis of seeing distances and times as continua, the second two, the arrow and the stadium, as showing the impossibility of motion on the theory of atomic space and time (Bostock, 1999:lviii).

Aristotle simply dismisses the arrow on the grounds that it works only with the quantised view of time which he rejects. At each instant of its flight the arrow is in a place exactly equal to its size; if a thing is in a place equal to its size it is motionless; if something is true of every instant during a period, its true of the entire period. So the arrow is always motionless.

Aristotle says this argument depends on assuming that time is composed of "nows", as duration-less limits. "But... time is not composed of indivisible nows..." (*Physics*, 239b, 7–8). So the argument fails. If time is made up of atoms, and everything is at rest during any one time atom, then everything is at rest in a period of time made up of such atoms. On Aristotle's continuum approach the motion of the arrow can be infinitely divided into periods of motion, so there are no such frozen moments of time in actuality.

It is possible to see that some sorts of atomic accounts could explain the relevant motion — providing we allow for instantaneous transitions and accept that what is true of every instant need not be true of the entire period. We can imagine a spacetime atom of empty space at location x being followed by a spacetime atom of front arrow occupancy, followed by back arrow occupancy, followed by empty space again and so on, as a way of getting the arrow across the requisite distance in the requisite time.

Insofar as each such spacetime atom is treated as a "frozen moment", such a "cinematic" model raises more problems than it solves, leaving the sequence in question completely unexplained. A.N. Whitehead's account, in *Process and Reality*, involves thoroughly dynamic spacetime atoms, or "actual occasions", as he calls them, absorbing and processing information from their own back light cones of preceding events, in order to determine their character as "empty space" or "arrow part" (Whitehead, 1929).

The dichotomy or racecourse paradox argues that before we can get from A to B we must get halfway, which takes time. This process of division can go to infinity — if Aristotle is right, and distances are infinitely divisible continua — however far we take the division we still have a distance to be covered. Because there are an infinite

instants. But there are potential infinities and potential instants. He defines such instants in terms of small intervals which compose larger intervals. "The potential limit of division of a time interval" into smaller and smaller "inner parts".

number of distances to traverse between A and B it will take an infinite amount of time to get there. So no-one can actually get anywhere.

Here again, quantised spacetime would imply a finite number of distances to be covered, a finite number of spacetime locations from start to finish with arrow parts propagated through them. But with frozen moments, this involves the same problems noted earlier. It remains to be seen whether any more dynamic conception could solve such problems.

Aristotle argues that if the distances are infinitely divisible, because they are continua, then so too are the relevant times — for time is continuous, no less than distance. Zeno treats time as finite in extension and distance as infinite by divisibility. But the distances and times in question are equally infinite by division. An infinite number of positions by division — can be traversed in a finite time by extension.[4]

## Einstein

Special relativity establishes that distances and durations are not invariant — or "objectively real" properties insofar as they depend upon the relative motion of inertial systems. However, application of the relevant formula allows the space and time measures from within different reference frames to be combined to form an invariant measure of the spacetime distance between events which observers in different frames can agree upon — the spacetime interval.[5]

All of Aristotle's ontologically primary substances have temporal and spatial properties, or more accurately, they have spatiotemporal properties — life-cycles — which are integral to their being the sorts of things they are. It therefore makes sense to understand his continuum of matter-in-process as a four dimensional spacetime continuum. But just as time and space have no substantial existence apart from the duration and physical extension of substances and their actions, neither does the — Aristotelian — continuum of spacetime have any such substantial existence apart from the existence of spatiotemporally extended substances and their interactions.

The problem is that in both special and general relativity theory, inertial motion is understood as the path forced upon a body by the structure of spacetime. There is an implicit assumption of a Euclidean geometry of absolute space in Newton's first law of motion. And it seems that special relativity replaces Newtonian absolute space with the spacetime totality of all possible inertial reference frames, as the cause of inertial forces.

4 Later Aristotle acknowledges that there is still a problem of getting through a minute if this requires getting through an infinite series of half-periods of time. And he again refers to the idea that there is no such infinity; there is no real "half" of a continuum; "an equal division puts an end to continuous movement and creates a standstill" (Aristotle, *Physics*, 263a).

5 Distances and durations measured in particular frames are treated as two sides of a right angled triangle, and a formula similar to Pythagoras's theorem gives the length of the third side [hypotenuse] of the triangle. For particular observers the interval between events is experienced and measured as a temporal duration or as spatial distance (in the former case, an observer present at both events, in the latter, an observer in a reference frame where the events are simultaneous).

Where for Aristotle there are only two basic ontological options, substance and void, contemporary theorists distinguish void, as lacking in determinate structure or dimensionality, from a space or spacetime whose geometrical structure directs or constrains the movement of matter. And Nerlich and others argue that the law-like connection between the intrinsic geometry of spacetime and the distribution of mass/energy in general relativity is not to be understood as a causal relationship. Geometrically directed motion is not the same as caused motion (Nerlich, 2010).

So, apparently, substantial spacetime can exist without being either substance or void — in Aristotle's sense — and it can manifest its presence other than through the exercise of a form-based causal power.

But perhaps all is not lost for Aristotelian relationism. As Sklar points out, the development of the concept of electric and magnetic field in late nineteenth century physics significantly changed ideas of the nature of the material world. Such fields were thought of as "extended over all space, with different intensities at different points" (Sklar, 1992:80).

In general relativity, spacetime itself has mass-energy. The geometry or shape of a particular quantity of matter is a paradigmatic Aristotelian form. A contemporary Aristotelian could argue that the geometrical structure or shape of spacetime is really the structure of a physical field, the metrical field, comprising gravitational energy and momentum. It is a form of such underlying matter, produced by the local distribution of mass/energy, the matter field, which confers a causal power to direct the motion of such mass/energy along geodesic — inertial — pathways.

## Conclusion

The relationist vs substantivalist debate remains alive, with Aristotle's relationist approach still very much worthy of consideration. Physics and philosophy continue to interact in fruitful ways in this area, with quantum gravity theories exploring new models of granular — substantival — spacetime. On the other side, quantum field theory leads to rejection of the idea of empty space as vacuum in favour of vacuum energy, which can be conceived as a perfect fluid with its own density and pressure. And general relativity implies that such "vacuum acts upon itself with repulsive gravitation" (Gron and Naess, 2011:309).

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